Dallas/Fort Worth International Airport Runway 17L and Dallas Love Field Runways 13L/R Instrument Landing System (ILS) Approach Procedures Interaction Analysis

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<td>The commissioning of the new east runway (17L35R) at Dallas/Ft. Worth International Airport (DFW), which is located 5,000 feet east of Runway 17C at Dallas Love Field (DAL), would preclude continued independent operations of these two airports using existing procedures when instrument meteorological conditions prevail. A team was formed consisting of representatives of the Federal Aviation Administration (FAA), DFW International Airport, Aircraft Owners and Pilots Association (AOPA), pilot unions, and air carriers that serve either or both airports, which considered eight alternatives that would allow the two airports to operate independently and at full capacity. The alternative utilizing a final monitor radar position within the DFW TRACON was identified as the most viable and the most acceptable of the eight alternatives. Several real time simulations were conducted by DFW TRACON to verify the feasibility of this alternative and a risk analysis was completed by the FAA Flight Procedure Standards Branch (AFS-420). The risk analysis indicated that the target level of safety would be met while using the final monitor radar position, but would not be met without the final monitor radar position.</td>
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EXECUTIVE SUMMARY

The location and runway alignments of Dallas/Fort Worth International Airport (DFW), in relation to the adjacent airport, Dallas Love Field (DAL), creates a situation in which the Instrument Landing System (ILS) courses for the two airports intersect when in a south arrival configuration. The point of intersection is approximately 6 nautical miles (NM) north of the approach end of Runway 17C at DFW.

Prior to the commissioning of the new east runway, 17L/35R at DFW, standard 3 NM lateral separation existed between arrival aircraft utilizing Runway 17C at DFW and those aircraft being radar vectored for arrival to Runways 13L/R at DAL. These independent operations operated at the maximum capacity permitted by the runways. The DAL procedures utilized a dog leg segment to the final approach course that ensures 3 NM lateral separation between the two final approach courses.

The commissioning of the new east runway, 17L/35R at DFW, which is located 5,000 feet east of Runway 17C, would preclude continued independent operations of these two airports using existing procedures when instrument meteorological conditions prevailed.

Under the original plans, procedures were developed in which these two airports could continue to operate independently at full capacity. In a review of the proposed procedures prior to implementation, concerns were raised by DFW and representatives of the aviation community serving both airports regarding these procedures.

These concerns were: (a) protracted flight at 2,000 feet under power creating possible noise issues, (b) an unusual descent profile, glide path angle, and (c) fuel consumption. A team consisting of representatives of the Federal Aviation Administration (FAA), DFW, Aircraft Owners and Pilots Association (AOPA), pilot unions, and air carriers that serve either or both airports.

In an effort to reduce the perceived impact of these concerns, the FAA, Southwest Region Charter Program Office, and DFW Terminal Radar Approach Control (TRACON) proposed eight alternatives for review and consideration by the analysis team.

The review resulted in the following conclusions:

a. **Alternative 1**: (Original Plan). After consultation with representatives of the users, DFW, and DFW TRACON, and with consideration given to the environmental impact, procedures on the ILS finals, and the flyability of the ILS procedures, it was determined this alternative was unacceptable.
b. **Alternatives 2 - 6:** These alternatives were determined to be unacceptable for several reasons. Each alternative either requires:

1. A significant loss of capacity at either DAL or DFW Airport.
2. Complex navigation procedures.
3. Environmental study to address major changes in procedures and flight tracks.

(c. **Alternative 7:** This alternative, which provides positive GPS course navigation during transition to the ILS courses, is the most desirable of the group. However, consideration must be given to the fact that precision approach procedures to implement this alternative are not available now, and it is unknown when these procedures will become available. Additionally, there would be a segment of the general aviation community that currently uses DAL that would never be able to utilize this procedure due to the cost of equipment that must be borne by the aircraft owner. Therefore, this alternative is not practical in the near term.

d. **Alternative 8:** This alternative provides an equal level of safety through the utilization of a final monitor radar position within the DFW TRACON to ensure the arrivals for DAL remain within their protected airspace and do not conflict with arrivals to DFW.

Alternative 8 was identified as the most viable and the most acceptable of the eight alternatives.

Subsequent to this determination, several real time simulations were conducted by DFW TRACON to verify the feasibility of this alternative. Upon completion of these simulations, a risk analysis was performed by the Flight Procedure Standards Branch (AFS-420), at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma.

Upon completion of the risk analysis, and a thorough briefing by representatives of AFS-420 to the members of the study group, all members of the group accepted the procedures outlined in Alternative 8. Subsequent action by DFW TRACON instituted these procedures upon the commissioning of Runway 17L at DFW.
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1.0 BACKGROUND.

The location and runway alignments of Dallas/Fort Worth International Airport (DFW) in relation to the adjacent airport, Dallas Love Field (DAL), creates a situation in which the Instrument Landing System (ILS) courses for the two airports intersect when in a south arrival configuration. The point of intersection is approximately 6 NM north of the approach end of Runway 17C at DFW. See figure 1.

For many years, air traffic procedures, which included a radar vectored dog leg to the final approach course for aircraft arriving Runways 13L/R at DAL, were used during instrument meteorological conditions. Sufficient distance remained between the two airports to permit independent operations of the arrival aircraft and maintain the required 3 NM lateral radar separation standard between the aircraft landing at both airports. See figure 2. Aircraft landing at DAL were radar vectored to intercept the ILS course for either Runway 13L or 13R approximately 7 NM northwest of the airport. Aircraft utilizing the ILS course to Runway 17C at DFW were established on the ILS course approximately 10 NM north of the airport.

On October 1, 1996 the new east runway, 17L/35R at DFW, was commissioned. Utilization of this new runway, located 5,000 feet east of Runway 17C, will reduce the minimum lateral separation between the aircraft arriving at DAL and the aircraft arriving on Runway 17L to 2 NM. See figure 3. In order to maintain an independent operation of these two arrival flows, and sustain the capacity of both airports during instrument meteorological conditions, resolution of the loss of lateral separation will be required.

During the planning phase for the new east runway at DFW, it was determined that separation of aircraft on the approach to Runway 17L and Runway 13/LR be provided through the utilization of vertical separation. Under this scenario the aircraft utilizing the ILS approach for Runway 17L at DFW would descend to 2,000 feet mean sea level (MSL) at a point approximately 10 NM north of the approach end of the runway. The aircraft would then maintain 2,000 feet until intercepting the glideslope of the ILS, which would occur 4 NM from the runway.

The glideslope of the ILS serving DAL are established at 3°. By elevating the glideslope to 3.25°, the altitude at which the aircraft are radar vectored to intercept, the ILS course could be raised to 3,000 feet MSL. The aircraft utilizing the ILS approach to DAL would maintain 3,000 feet until established on the ILS course.

Accomplishment of these two actions would provide the required 1,000-foot vertical separation during that phase of flight in which these two aircraft are laterally separated by less than 3 NM. Upon review of the Environmental Impact Statement (EIS) prepared for DFW, to support the construction of the new runways, it was determined that elevation of the glideslope at DAL was not a feasible course of action. Based upon this determination representatives of the Southwest Region Charter Program Office, DFW Terminal Radar Approach Control (TRACON),
FIGURE 1. DALLAS/FT. WORTH AND DALLAS LOVE AIRPORTS PRIOR TO RUNWAY 17L
FIGURE 2. APPROACH OPERATIONS PRIOR TO RUNWAY 17L
FIGURE 3. DALLAS/FT. WORTH AND DALLAS LOVE AIRPORTS WITH RUNWAY 17L
Aircraft Owners and Pilots Association (AOPA), and the air carriers serving both airports initiated a study to resolve the problem.

2.0 REPRESENTATIVES.

Resolution of this issue required the involvement of the Federal Aviation Administration (FAA), DFW, and the aviation community. A committee was formed to analyze, recommend, and agree upon the resolution action. This committee consisted of the following representatives:

a. Southwest Regional Office
b. DFW Terminal Radar Approach Control Facility
c. Flight Procedure Standards Branch (AFS-420), Oklahoma City, Oklahoma
d. Dallas/Fort Worth International Airport
e. American Airlines
f. Delta Airlines
g. Southwest Airlines
h. Atlantic Southeast Airlines
i. American Eagle
j. Air Transport Association (ATA)
k. Airline Pilots Association (ALPA)
l. Aircraft Owners and Pilots Association (AOPA)
m. Allied Pilots Association (American Airlines)
n. Southwest Airlines Pilots Association
o. National Air Traffic Controller Association (NATCA), Local Office
q. D10/DFW TRACON
r. DFW TRACAB
s. Dallas Love Field

3.0 ALTERNATIVES.

The alternatives listed in this section were developed by the representatives listed in paragraph 2.0. The objective of each of these alternatives is to provide a safe and efficient system which would permit the continued independent operation of DFW and DAL.

3.1 Alternative 1 - Vertical Separation. This alternative requires DFW Runway 17L arrivals to cross a point 10 NM north of the runway threshold at a mandatory altitude of 2,000 feet MSL or 1,500 feet Above Ground Level (AGL). The arrivals to DFW would be on the ILS course while the DAL arrivals would be on a radar vector to the Runway 13L/R final approach course. DAL arrivals would be required to intercept the Runway 13L/R final approach course at 3,000 feet MSL and remain at 3,000 feet until established on a diverging course from the aircraft on the ILS course to Runway 17L at DFW.
FIGURE 4. ALTERNATIVE 1 - VERTICAL SEPARATION

Aircraft cross at 2,000 feet MSL

1,000-foot vertical separation between aircraft landing Rwy 17L and aircraft landing Rwy 13L/R

3 NM lateral separation between aircraft landing Rwy 17C and aircraft landing Rwy 13L/R

Aircraft maintain 5,000 feet until established on ILS

Aircraft maintain 2,000 feet until the Outer Marker

Aircraft maintain 3,000 feet until established on ILS

ILS Glide Slope changes to 3.25 degrees

Dallas/Fort Worth International Airport

Dallas Love Field

Cowboy DVOR/DME

Dallas/Fort Worth Cowboy DVOR/DME

Dallas Love Field

18R 17C

10 NM Fix

17L

13L

13R
3.2 Alternative 2 - Common Arrival Queue. This alternative would utilize a
dependent arrival flow to the two airports. Aircraft destined for either airport would be vectored
into the same arrival sequence north of the final approach courses.

3.3 Alternative 3 - Parallel Approach. This alternative requires DAL arrivals to be
established on a course parallel to the aircraft utilizing Runway 17L at DFW's final approach
course prior to loss of vertical separation. The DAL arrivals would be required to utilize a
navigational aid (VOR, LDA, etc.) to establish the parallel course. This parallel portion would
be monitored by a final monitor position until the DAL arrival turned final and was established
on a diverging course. In essence, simultaneous parallel ILS approach procedures would be
applied to aircraft landing at different airports.

3.4 Alternative 4 - VOR/DME Approach Using Cowboy DVOR/DME. This
alternative requires the design, flight inspection, and publication of a non-precision instrument
approach utilizing the Cowboy Doppler Very High Frequency Omni-directional Radio Range
with Distance Measuring Equipment (DVOR/DME) facility. Due to the location of the Cowboy
DVOR/DME, the approach to Runway 13L/R would terminate a considerable distance from the
airport.

3.5 Alternative 5 - Positive Course Guidance Transition. This alternative would
require DAL arrivals be established on a DFW Very High Frequency Omni-directional Radio
Range with Tactical Air Navigation (VORTAC) radial as a transition route to the ILS courses
serving DAL. This would create positive course navigation for the aircraft prior to intercepting
the ILS courses.

3.6 Alternative 6 - ILS Approach to Runway 18 at DAL. This alternative
requires the installation of ILS equipment and approach light system on Runway 18 at DAL.

3.7 Alternative 7 - Global Positioning System (GPS). GPS equipment would be
used to provide positive navigation during the transition from en route to the ILS final approach
courses serving DAL. This alternative requires the final validation and implementation of the
GPS technology for instrument flight rules (IFR) en route procedures. The current estimate to
date of system wide GPS is 1997. There are several airlines currently testing the technology and
standards are being updated to reflect the precision of GPS.

3.8 Alternative 8 - Monitored Reduced Separation. This alternative requires a
waiver to standard IFR separation since the interception of the final approach course to Runway
13R at DAL would occur only 2 NM from the approach to Runway 17L at DFW. A dedicated
radar monitor position would ensure an equivalent level of safety will be maintained.
Aircraft maintain 3,000' feet MSL

Aircraft landing Rwy 17L and Rwys 13L/R must have 3 miles lateral in-trail separation until those aircraft landing Rwys 13L/R turn and intercept the ILS Rwys 13L/R.

Aircraft maintain 5,000 feet until established on ILS

Aircraft maintain 2,000 feet until the Outer Marker

Dallas/Fort Worth International Airport

Cowboy DVOR/DME

Dallas Love Field
Aircraft maintain 3,000 feet MSL until established on Rwy 17L ILS. Aircraft must be established on parallel route prior to loss of vertical separation with aircraft on ILS Rwy 17L.
FIGURE 7. ALTERNATIVE 4 - VOR/DME APPROACH USING COWBOY DVOR/DME

18R 17C
Aircraft maintain 3,000 feet MSL until established on Rwpy 17L ILS

17L
Aircraft maintain 5,000 feet until established on ILS

Dallas Fort Worth International Airport
Cowboy DVOR/DME
Dallas Love Field

Initial Approach Fix
Radial from Cowboy VOR/DME
3 NM
FIGURE 8. ALTERNATIVE 5 - POSITIVE COURSE GUIDANCE TRANSITION

- Aircraft maintain 3,000 feet MSL until established on Rwy 17L ILS
- Radial from DFW VORTAC
- Cowboy DVOR/DME
- Dallas Love Field
- Dallas/Fort Worth International Airport

Aircraft maintain 5,000 feet until established on ILS
Aircraft maintain 5,000 feet MSL until established on Rwy 17L ILS.

Outer Marker Initial ILS Approach Fix

Dallas/Fort Worth International Airport

Dallas Love Field

Cowboy DVOR/DME

3 NM

5 NM

Figure 9. Alternative 6 - ILS Approach to Runway 18
AT DAL
Aircraft maintain 3,000 feet MSL until established on Rwy 17L ILS

Initial Approach Fix

GPS Approach

Cowboy DVOR/DME

Dallas/Fort Worth International Airport

Dallas Love Field

18R 17C

Aircraft maintain 5,000 feet until established on ILS

GPS Waypoints

3 NM
Aircraft maintain 3,000 feet MSL until established on Rwy 17L ILS.

Aircraft maintain 5,000 feet until established on ILS.

No Transgression Zone.

2 NM.

Monitored Radar Vectors Rwy 17L and Rwys 13L/R.

Cowboy DVOR/DME.

Dallas/Fort Worth International Airport.

Dallas Love Field.
4.0 ANALYSIS.

The objective of this analysis was to evaluate all alternatives available to support the continued independent operation of the two airports and determine which procedure is the optimum for all entities involved in the system. In addition, the procedure must maintain safety, efficiency of the system, and be environmentally sensitive.

Each alternative was analyzed based upon the following categories:

a. Capacity
b. Environment
c. User’s Viewpoint
d. Procedures
e. Cost
f. Other Considerations

4.1 Alternative 1 - Vertical Separation.

4.1.1 Capacity. Independent traffic flows would be established and maintained at both airports. DFW Runway 17L could be utilized as a full arrival runway.

The runways at DAL do not permit simultaneous parallel independent ILS procedures. Since runway centerline separation is 2,950 feet, staggered approaches with 1.5 miles between successive arrivals on the two runways is required. A minimum of 3 NM separation is required between aircraft on the same approach.

4.1.2 Environmental. There are several significant environmental impacts to consider. The arrivals to DFW would be forced to descend to 2,000 feet MSL, at least 10 NM from the approach end of the runway. This descent places the aircraft approximately 2,800 feet below the normal glideslope altitude at the IO NM fix. In order to maintain altitude, the aircraft will need to add engine power. The lower altitude creates noise and visible pollution, which would be worsened by the necessity to increase power.

4.1.3 User's Viewpoint. A non-standard approach descent would be required due to the design of the descent profile for Runway 17L at DFW. The profile requires a mandatory descent prior to glideslope intercept. The arrival aircraft would maintain level flight for several miles before intercepting the glideslope at the outer marker. This would increase fuel consumption due to the added power for level flight and would not permit a smooth, gradual descent to landing. Another adverse impact would be the increased glideslope for the DAL final approaches. The standard glideslope is 3.0°. In order to utilize 3,000 feet MSL as a final approach course intercept altitude for Runways 13L/R, the glideslope angle would have to be increased to 3.25°. This steeper descent angle requires descent rates in excess of 1,000 feet per minute and does not conform to the majority of the published instrument approach procedures.

4.1.4 Procedures. Standard IFR separation would be applied.
4.1.5 **Cost.** The only costs are those associated with the relocation of the glideslope equipment for both Runways 13L/R at DAL and the flight inspection requirements to place the systems in service.

4.1.6 **Other Considerations.** Independent traffic flows would be established and maintained at both airports and the runways could be utilized to full capacity.

4.1.7 **Recommendation for Alternative 1.** The procedure is feasible and meets requirements for IFR approaches; however, this procedure is not preferred for reasons expressed in subparagraphs 4.1.2 and 4.1.3.

4.2 **Alternative 2 - Common Arrival Queue.**

4.2.1 **Capacity.** Capacity at both airports would be severely constrained. A single dependent arrival flow would have to be utilized and would significantly reduce the capacity of both airports. The diverse operating characteristics of the aircraft using both airports would further reduce capacity of both airports. The arrival capacity of DAL would be reduced by a minimum of 50 percent and the new runway at DFW would only increase the capacity of the airport by an amount equivalent to 50 percent of the arrival figure normally associated with an independent arrival runway.

4.2.2 **Environmental.** No adverse environmental impacts would occur.

4.2.3 **User's Viewpoint.** Due to the diverse mixture of aircraft, heading and speed adjustment would occur more frequently while maintaining a single flow to two separate airports.

4.2.4 **Procedures.** Standard 3 NM in-trail IFR separation would be applied.

4.2.5 **Cost.** There are no costs to the FAA involved in this alternative. However, there would be costs to DFW and the aviation community. DFW would suffer less return on the investment for the runway due to reduced runway capacity created by the mixing of the arrival flows. The aviation community costs would be in reduced capacity of both airports created by the mixing of the two arrival flows and longer final approach segments.

4.2.6 **Other Considerations.** The application of these procedures to aircraft landing at different airports would increase controller workload and complexity due to the diverse mixture of aircraft.

4.2.7 **Recommendation for Alternative 2.** The procedure is feasible and meets requirements for IFR approaches; however, this procedure is not preferred because of reasons expressed in subparagraphs 4.2.1 and 4.2.3.
4.3 Alternative 3 - Parallel Approach.

4.3.1 Capacity. This alternative requires the design, validation, and publication of a new standard instrument approach procedure. Full capacity to Runway 17L at DFW could be maintained, although the length of the final approach segment would be extended to accommodate the aircraft arriving at DAL. However, capacity at DAL would be reduced. In order to apply simultaneous parallel ILS approach procedures, it would be necessary for DAL arrivals to be placed on a flight track, which would commence approximately 15 NM north of the airport. This flight track would reduce the overall capacity of the airport because slower aircraft would be required to mix with faster aircraft at a greater distance from the airport. Additionally, parallel ILS approaches to the two parallel runways of DAL, even with a staggered arrangement, could not be utilized.

4.3.2 Environmental. Arrival aircraft for DAL would be required to overfly an area that is not currently under an approach to either airport. A formal assessment of the environmental impact would be required.

4.3.3 User's Viewpoint. Heading and speed adjustments for aircraft landing at DAL would occur more frequently due to the diverse mixture of aircraft. Moreover, a pilot would be required to navigate utilizing two guidance systems on the approach to DAL. The initial guidance system would route the aircraft on a course parallel to the approach course for Runway 17L at DFW. The transition between the two navigation systems (VOR/GPS - ILS) during a crucial phase of the approach would increase cockpit workload and complexity with a corresponding decrease in safety.

4.3.4 Procedures. A waiver authorizing the use of simultaneous parallel ILS approach procedures between two different airports would be required. The actual procedures would emulate the current simultaneous operations.

There are additional considerations. DFW will be operating triple parallel simultaneous ILS approach procedures with the commissioning of Runway 17L. Implementation of the procedures described in this section would in fact create quadruple simultaneous parallel ILS approach procedures serving two separate airports. Quadruple ILS procedures have been approved for operation when the new west runway becomes operational at DFW. The addition of DAL would create a situation in which there would be 5 aircraft on parallel approaches to two different airports which has never been studied or approved. Approval of this type of procedure would require a new study, simulations, and several years to accomplish.

4.3.5 Cost. There would be several separate costs incurred in this alternative because of the following requirements: (a) a study to validate the procedure for 5 parallel simultaneous independent ILS approach procedures, (b) simulations of these procedures, (c) an additional radar position (DAL Final Monitor), (d) additional staffing, and (e) an additional navigation aid to support the parallel route prior to intercepting the ILS for either Runway 13L/R at DAL.
4.3.6 **Other Considerations.** Data block overlap is a serious problem for several positions within the TRACON. Utilization of this alternative will only intensify this problem for the Final Monitor positions serving both airports.

4.3.7 **Recommendation for Alternative 3.** This procedure is not preferred because of reasons expressed in subparagraphs 4.3.1 through 4.3.5.

4.4 **Alternative 4 - VOR/DME Approach Using Cowboy DVOR/DME.**

4.4.1 **Capacity.** Development of an instrument approach procedure utilizing the Cowboy DVOR/DME facility, located between the centerline of the runways northwest of DAL, 4 NM, would require an initial approach segment from the northeast. This segment would be followed by approximately a 100° left-turn at the Cowboy facility to deliver the aircraft to the runways.

The capacity of DAL would be reduced due to the in-trail separation distances requirements caused by the wide variety of aircraft that would utilize the approach procedure. The IFR capacity would be adversely impacted due to the high minimums for the approach. In fact, during low ceiling/visibility conditions, a dependent arrival flow would have to be established to conduct operations to Runway 17L at DFW and DAL. With the exception of the dependent flow during low ceiling/visibility conditions, full capacity would be maintained for Runway 17L at DFW.

4.4.2 **Environmental.** There would be no adverse environmental impact under this alternative.

4.4.3 **User's Viewpoint.** This alternative utilizes a non-precision approach during IFR weather conditions with an ILS available to the same runway. This would be a regression from the current procedures.

4.4.4 **Procedures.** Standard radar separation would be utilized. Complexity to the radar position controlling the final approach courses to ADS and DAL would be increased due to the potential for crossing DAL arrivals above the aircraft on downwind leg and final approach for ADS.

4.4.5 **Cost.** The cost of this alternative would be the development, flight inspection, and publication of the procedure.

4.4.6 **Other Considerations.** This approach would increase the interaction between the traffic patterns of DAL and ADS and delays at DAL would likely occur. Additionally, specific approval from Flight Standards would have to be obtained to implement an approach for fixed wing aircraft that terminates at a point in space.

4.4.7 **Recommendation for Alternative 4.** This alternative is not preferred because of reasons expressed in subparagraphs 4.4.1, 4.4.3, 4.4.5, and 4.4.6.
4.5 Alternative 5 - Positive Course Guidance Transition.

4.5.1 Capacity. Independent traffic flows would be established and maintained at both airports. Runway 17L at DFW could be utilized as a full arrival runway. There would be a slight reduction in capacity at DAL due to the decreased utilization of parallel ILS approaches.

4.5.2 Environmental. Although there would be minimal change to the current flight tracks, an environmental assessment would be required.

4.5.3 User's Viewpoint. Pilots would be required to navigate utilizing two guidance systems on approach to DAL. The initial guidance system (VOR) would route the aircraft on a course based upon a DFW VORTAC radial. The aircraft would then be required to intercept the ILS final approach course at DAL. The transition between two navigation systems during a crucial phase of the approach would increase cockpit workload and complexity.

4.5.4 Procedures. A waiver would be required to permit the use of reduced lateral separation and the use of a Dallas final monitor position. The Dallas final monitor position would be responsible for ensuring that DAL arrivals remained within the confines of the VORTAC transition and localizer intercept course. All DAL arrivals would be required to intercept the DFW VORTAC transition. This procedure would reduce flexibility and diminish the airspace available for sequencing.

4.5.5 Cost. An additional radar position, Dallas Final Monitor and staffing for the position would be required. The cost of development of the procedure, flight inspection, and publication would also be incurred.

4.5.6 Other Considerations. Other considerations are not a factor on this alternative.

4.5.7 Recommendation for Alternative 5. This alternative is not preferred because of reasons expressed in subparagraphs 4.5.1, 4.5.2, 4.5.3, 4.5.4, and 4.5.5.

4.6 Alternative 6 - ILS Approach to Runway 18 at DAL.

4.6.1 Capacity. Independent traffic flows would be established and maintained between DAL and DFW. Runway 17L at DFW could be utilized at full capacity. DAL would be unable to conduct parallel ILS approach procedures.

Additionally, Runway 18 is 6,149 feet in length, approximately 2,000 feet shorter than Runways 13L/R. Moreover, since there are no high speed exits on Runway 18, runway occupancy time would be increased. Finally, utilizing Runway 18 as a full time arrival runway would increase departure delays due to increased interaction between departing and arriving aircraft due to because of the crossing runway scenario.
This alternative has definite adverse impact on the arrival and departure operations of Addison Airport (ADS) because the final approach course extends directly across ADS.

4.6.2 **Environmental.** The significant increase in the use of Runway 18 at DAL would have adverse noise impact on the communities north of the airport. An environment assessment or possibly an EIS would be required.

4.6.3 **User's Viewpoint.** The reduced runway length would eliminate some types of aircraft from utilizing this alternative.

4.6.4 **Procedures.** Standard air traffic control separation would be utilized. This alternative has adverse procedural impact on the East Satellite Radar Positions in the DFW TRACON. Arrivals to ADS would have to be sequenced with the DAL arrivals to protect a possible missed approach at ADS. Also, procedures for the airport traffic pattern of ADS would require modification due to the low altitude of the arrivals to DAL in the immediate vicinity of ADS.

4.6.5 **Cost.** This alternative has a significant added cost with purchase of the ILS equipment and associated approach light system. Additionally, there are costs of completion of the environment assessment or EIS, procedural development, flight inspection, publication, and maintenance of the equipment.

4.6.6 **Other Considerations.** The utilization of an ILS procedure to Runway 18 would increase the amount of intersecting runway operations at DAL. Intersecting runway operations have a higher potential for error and generally are not capacity enhancing.

4.6.7 **Recommendation for Alternative 6.** This alternative is not preferred because of reasons expressed in subparagraphs 4.6.1 through 4.6.6.

4.7 **Alternative 7 - Global Positioning System (GPS).**

4.7.1 **Capacity.** Independent traffic flows would be established and maintained at DFW and DAL. Runway 17L at DFW and Runway 13L/R at DAL could be utilized at full capacity.

4.7.2 **Environmental.** An environmental assessment would be required for the establishment of a new approach procedure for DAL. The majority of the flight tracks required for the GPS approach reflect those in use at the present time.

4.7.3 **User's Viewpoint.** The purchase of GPS equipment would be required. The predicted cost for the equipment is very reasonable and early indications are that many aircraft would be equipped with GPS. However, it is likely that a significant percentage of the general aviation aircraft that currently operate at DAL would be excluded due to the cost of a GPS receiver.
4.7.4 Procedures. Standard air traffic control separation would be utilized. The procedures would include features that would provide air traffic control optimum sequencing flexibility.

4.7.5 Cost. The cost of this alternative is unknown. The technology is in the early stages of development with no absolute estimates on ground-based equipment requirement, costs, or availability.

4.7.6 Other Considerations. There are no other factors under this alternative.

4.7.7 Recommendation for Alternative 7. This alternative would be preferred if GPS receivers and approach procedures were currently available. However, it is unknown at this time when GPS will be approved to provide guidance for the transition to the ILS approaches at DAL and how much time after that the fleet will be appropriately equipped. Therefore, this alternative is not viable at the present time.

4.8 Alternative 8 - Monitored Reduced Separation.

4.8.1 Capacity. Independent traffic flows would be established and maintained between DFW and DAL. Runway 17L at DFW and Runway 13L/R at DAL could be utilized at full capacity.

4.8.2 Environmental. Runway 17L arrivals at DFW would utilize a glideslope descent which is reflected in the EIS and noise sensitive to the surrounding communities. There would be no change to the current ground track of the DAL arrivals.

4.8.3 User's Viewpoint. Instrument flight rules aircraft would have less lateral separation than current procedures require and there may be a lack of acceptance of reduced separation by the pilot community.

4.8.4 Procedures. A waiver permitting reduced lateral separation and final approach course intercept at the approach gate would be required. The waiver would also outline a No Transgression Zone (NTZ) and responsibilities for a final monitor position which would monitor and ensure separation between the arrivals for DAL and the arrivals utilizing Runway 17L at DFW.

4.8.5 Cost. This alternative adds the cost of an additional radar monitor position and required staffing.

4.8.6 Other Considerations. The actual amount of time an aircraft occupies airspace in which less than 3 NM lateral separation will be used would be very limited. The radar monitor position would monitor the airspace and be equipped with frequency override capabilities to ensure instant communication. The NTZ would be designed to contain arrivals to DAL within the applicable airspace. A simulation can be performed to determine whether the two NM separation introduces an additional, unacceptable risk.
4.8.7 Recommendation for Alternative 8. This alternative is the most acceptable to the study committee. Full capacity of the runways at both airports would be achieved without an additional environmental impact study. A simulation of the traffic procedures utilizing the final monitor position is required to satisfy user groups and the study committee. An additional, unacceptable risk is not introduced.

5.0 SUMMARY.

A review of paragraph 4.0 analysis indicates all the alternatives have special requirements, impacts, cost, and considerations that must be evaluated. The following is a summary of the analysis of the eight alternatives.

5.1 Alternative 1. This is the original resolution to the issue and would have provided an unrestricted arrival flow to both DFW and DAL. However, after consultation with the representatives of the users, DFW, and DFW TRACON, it was determined this alternative is not acceptable.

5.2 Alternatives 2 - 6. These alternatives were determined to be unacceptable for several reasons. Each alternative either requires:

- a. A significant loss of capacity at either DAL or DFW.
- b. A significant increase in cost of equipment.
- c. Some form of environmental study that requires time and/or funds to accomplish.

5.3 Alternative 7. This alternative is the most desirable of the group. The alternative provides positive GPS course navigation during the transition to the ILS courses and it would most likely be the least expensive to implement.

Precise procedures to implement this alternative are not available now. The time frame at which these procedures will become available is unknown. There would be a segment of the general aviation community that currently uses DAL and would never be able to utilize this procedure due to the cost of equipment that must be borne by the aircraft owner. Therefore, this alternative is not practical as a near term solution for all facets of the user community.

5.4 Alternative 8. This alternative provides an equal level of safety through the utilization of a final monitor radar position within the DFW TRACON to ensure the arrivals for DAL remain within their protected airspace and do not affect the arrivals to DFW. Additionally, this alternative permits full utilization of the runways at DAL and DFW.

A radar monitor is available in the DFW TRACON for use in this new position and staffing of the facility is sufficient to absorb the additional position.
Acquiring a waiver of reduced lateral radar separation can be obtained through FAA channels in a relatively short period of time pending validation of the procedures.

It was the consensus of the representatives of the meeting that alternative 8 was acceptable and should be implemented. Figure 11 depicts these procedures.

6.0 SIMULATIONS.

While the representatives of the user groups accepted the findings of the alternatives study, questions were raised concerning the actual procedures to be used. The development of a real time simulation to demonstrate the viability of alternative 8 was the only avenue for resolution.

DFW TRACON conducted several real time simulations using their training facilities, radar systems, computer equipment, and controller personnel to demonstrate the practices to be employed under alternative 8.

The simulations conducted using the Enhanced Target Generator training facility used copies of the actual traffic flows for DAL and DFW. Random unannounced blunders, in which the aircraft on either arrival flow made turns towards the adjacent aircraft with and without radio communication, were then induced to test the ability of the controllers to maintain the accepted minimum test criteria miss distance of 500 feet, either vertically or laterally.

These simulations validated the procedures and demonstrated to the observers that the controllers were able to provide the required air traffic instructions to maintain separation of the aircraft to the test criteria standards described above.

During the simulations, random acts were introduced into the tests on virtually a moments notice at the request of the observers on that particular simulation. All of these random acts were resolved by the controllers to meet and/or exceed the test criteria standards.

Under real time simulations the time required to complete each test run was approximately one hour. Therefore, the number of runs were limited by time. Upon completion of the real time simulations questions were raised by the user groups concerning the number of test runs completed.

The user groups requested a computer “Risk Analysis” be completed on the procedures. The objective of the “Risk Analysis” is by nature a computer based study that can be conducted on a 24-hour basis and at a speed far in excess of a real time simulation. In the time required for one “real time” simulation, several thousand “computer” simulations can be completed.

Representatives of the Southwest Region Charter Program Office and DFW TRACON conducted several meetings at the Mike Monroney Aeronautical Center (MMAC) in Oklahoma City, Oklahoma, with representatives of AFS-420. The objective of these meetings was the completion of a risk analysis study utilizing the Airspace Simulation and Analysis for Terminal Instrument Procedures (ASAT) computer system. Although this computer system was originally
developed for TERPS applications, the system was designed for flexibility and can be used in a wide variety of situations. The ASAT system was used to generate a database, which could be used to determine the risk of collision under the procedures outlined in alternative 8.

7.0 RISK ANALYSIS OF BLUNDERs.

7.1 Introduction. The addition of runway 17L at the DFW airport will introduce the risk of collision of aircraft on the approach to DFW with aircraft on approach to runways 13L/R at DAL. Because of the geographical location and the differing approach headings of the two airports, the localizer intercept segment of the ILS approach to runway 13R will be in close proximity, about 2 NM, to the ILS approach to 17L. Because of altitude differences and the narrow dispersion of cross-track error on an ILS approach, normal approaches to each airport will pose no significant risk. However, if an aircraft fails to intercept the localizer for the 13L/R approach to DAL, or if an aircraft on the ILS approach to 17L at DFW turns toward the traffic pattern at DAL, or if an aircraft on the ILS approach to 17L at DFW executes a missed approach, then the risk of a collision exists. It is the purpose of this study to estimate the risk of collision of aircraft on the two neighboring airports.

Since the pattern of arriving traffic at the two airports is complex, an analytical solution would be intractable. However, the arriving traffic can be effectively modeled by a computer simulation. The Flight Procedure Standards Branch has developed a multipurpose, high fidelity computer system called ASAT. Although originally developed for TERPS applications, the system was designed for flexibility and can be used in a wide variety of situations. The ASAT system was used to generate a database, which could be used to determine the risk of collision.

7.2 Simulation Using ASAT.

7.2.1 General Description of ASAT. The ASAT system is structured in such a way that a complex operation, such as the traffic pattern at DFW and DAL may be realistically and accurately simulated. The ASAT system consists of independent models, which were developed to simulate the primary determinants of the spatial position of the aircraft. The principle components of the ASAT system may be categorized as follows:

a. Geographic/Geometric Model. Consists of the latitude, longitude, elevation (and bearing, where applicable) of thresholds, ground navigation stations, and surveillance equipment.

b. Environmental Model. Consists of a full atmospheric model. The model includes variation of temperature, pressure, and density as a function of altitude and QNH, as well as winds.

c. Aircraft Model. Consists of several different models of the appropriate performance characteristics of various aircraft types.
d. **Navigation/Avionics/Surveillance Model.** Consists of models for on-board navigation equipment, such as ILS, flight management systems (FMS), and GPS. Included, are models of ILS transmitters and air traffic control radar systems.

e. **Human Factors Model.** Consists of pilot and controller models. These models have a predetermined set of actions, usually driven by discrete events. The databases for these models are generated by analyzing flight tests and/or flight simulator tests.

The program is structured so each model can be modified independently. For most applications, few if any, modifications are required for models 2 and 4. The aircraft model may be modified by the addition or omission of type specific aircraft to obtain a realistic traffic mix at a particular terminal area. Modifications to the Geographical/Geometric Model and the Human Factors Model are sometimes required because of unique operational requirements peculiar to a particular simulation.

### 7.2.2 ASAT Modifications

Some unique features were incorporated into the ASAT model especially for this simulation. These features were mainly related to the following models:

a. **Geographic/Geometric Model.** The model was modified to include all relevant runways on both airports. Runways of both airports graphically displayed on the computer monitor and the active runways, Runway 17L and Runway 13R, are highlighted for easy identification by the viewer. A boundary line is drawn 2 NM east and parallel to Runway 17L for traffic separation purposes.

b. **Aircraft Model.** The aircraft model included aircraft typical to the two airports, DFW and DAL. Data was provided by DFW TRACON personnel regarding the types of aircraft and the percentage of arrivals of each type of aircraft. Since a wide variety of aircraft are operated at the two airports, some aircraft types were replaced by aircraft types with similar performance characteristics. Table 1 and table 2 summarize the aircraft types and traffic mix simulated in this study. In order to provide realistic modes of operation, for the simulated aircraft, four line pilots employed by airlines conducting flight operations at DFW or DAL and one FAA pilot were consulted to determine typical approach parameters. From the consultation, ranges of indicated airspeeds used outside and inside the outer marker as well as deceleration rates were determined. The flight parameters such as bank angles and bank rates were also obtained. In addition, discrete data, such as the range of points where gear-down normally occurs and flaps are extended were determined as well as flap extension angles. Similar data for a missed approach were also determined. The operational data were incorporated into the model and resulted in realistic flight tracks of the simulated aircraft.

c. **Navigation/Avionics/Surveillance Model.** An additional monitoring model was developed to monitor the location and bearing of aircraft approaching Runway 13R relative to the 2 NM boundary line. The surveillance radar simulated in the study was the Airport Surveillance Radar System (ASR-9) with the Data Entry and Display Subsystem (DEEDS) display.
d. Pilot Model. Two models were modified to simulate approach operations unique to DFW and DAL. One pilot model was modified to execute the approach to Runway 13R under air traffic control guidance. This modification was necessary since two main traffic streams, from the southeast and northeast must be simulated. Pilot reaction times were based upon reaction times measured in previous real-time simulations.

e. Air Traffic Control Model. The air traffic control model was modified to monitor the 2 NM boundary line and react to aircraft that do not perform the final turn to intercept the localizer at Runway 13R. Air traffic control response times were based upon data acquired from a real-time or live simulation. The simulation was conducted at the DFW TRACON facility using the Radar Training Simulator. Aircraft traffic streams were simulated to Runway 17L and Runway 13R. At randomly selected times, simulated aircraft failed to intercept the localizer to Runway 13R or committed a 30° or a 90° blunder from Runway 17L toward Runway 13R at DAL. Twelve certified air traffic controllers employed at the DFW TRACON monitored the traffic streams and directed the errant aircraft to return to the localizer or other appropriate action. Data was collected over a two day period with two three hour sessions per day. The reaction times of the controllers were recorded resulting in sixty six data points. The recorded times range from 12.2 seconds to 38.68 seconds. A continuous probability curve was fitted to the data and the continuous curve was used in the ASAT simulations to provide randomly selected controller reaction times. The set of controller response times, along with descriptive statistics, is presented in table 3.

Air traffic control logic was developed after consultation with four certified air traffic controllers employed at the DFW TRACON. The consultation provided information regarding vectoring procedures to the Runway 13R localizer and separation procedures for aircraft that fail to intercept the localizer. Information regarding separation procedures for aircraft breaking out of the Runway 17L localizer toward the Runway 13R traffic stream was also obtained.
Table 1. AIRCRAFT TRAFFIC MIX AT DFW.

<table>
<thead>
<tr>
<th>Aircraft Operation at DFW</th>
<th>Percent of Total Traffic</th>
<th>Percent in the Simulation</th>
<th>Assigned Type in the Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD-80/88/90</td>
<td>35</td>
<td>35</td>
<td>MD-80</td>
</tr>
<tr>
<td>FK-10</td>
<td>19</td>
<td>19</td>
<td>MD-80</td>
</tr>
<tr>
<td>B-757</td>
<td>8</td>
<td>8</td>
<td>B-747</td>
</tr>
<tr>
<td>SF-34</td>
<td>8</td>
<td>8</td>
<td>ATR-72</td>
</tr>
<tr>
<td>ATR-42</td>
<td>3</td>
<td>3</td>
<td>ATR-42</td>
</tr>
<tr>
<td>ATR-72</td>
<td>3</td>
<td>3</td>
<td>ATR-72</td>
</tr>
<tr>
<td>B-767</td>
<td>5</td>
<td>5</td>
<td>B-747</td>
</tr>
<tr>
<td>B-727</td>
<td>5</td>
<td>5</td>
<td>B-737</td>
</tr>
<tr>
<td>B-737</td>
<td>4</td>
<td>4</td>
<td>B-737</td>
</tr>
<tr>
<td>E-120</td>
<td>3</td>
<td>3</td>
<td>ATR-42</td>
</tr>
<tr>
<td>SW-3/4</td>
<td>2</td>
<td>2</td>
<td>ATR-42</td>
</tr>
<tr>
<td>DC-10</td>
<td>1</td>
<td>1</td>
<td>B-747</td>
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<tr>
<td>MD-11</td>
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</tr>
<tr>
<td>DC-8</td>
<td>1</td>
<td>1</td>
<td>B-737</td>
</tr>
<tr>
<td>L1011</td>
<td>1</td>
<td>1</td>
<td>B-747</td>
</tr>
<tr>
<td>Corporate Jet</td>
<td>1</td>
<td>1</td>
<td>MD-80</td>
</tr>
</tbody>
</table>

Table 2. AIRCRAFT TRAFFIC MIX AT DAL.

<table>
<thead>
<tr>
<th>Aircraft Operational at DAL</th>
<th>Percent of Total Traffic</th>
<th>Percent in the Simulation</th>
<th>Assigned Type in the Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-737</td>
<td>47</td>
<td>47</td>
<td>B-737</td>
</tr>
<tr>
<td>Corporate Jet</td>
<td>20</td>
<td>20</td>
<td>MD-80</td>
</tr>
<tr>
<td>Light Twin</td>
<td>10</td>
<td>10</td>
<td>ATR-42</td>
</tr>
<tr>
<td>Turboprop</td>
<td>10</td>
<td>10</td>
<td>ATR-42</td>
</tr>
<tr>
<td>Single</td>
<td>10</td>
<td>10</td>
<td>ATR-42</td>
</tr>
<tr>
<td>B-727</td>
<td>2</td>
<td>2</td>
<td>B-737</td>
</tr>
</tbody>
</table>

Table 3. CONTROLLER RESPONSE TIMES (SEC).

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23.71666667</td>
<td>0.263642267</td>
<td>-0.920226314</td>
</tr>
</tbody>
</table>
7.2.3 Simulation Scenarios. Six blunder scenarios were designed to simulate blunders at DFW or DAL as follows:

**Scenario 1:** An aircraft being vectored to the localizer to Runway 13R flies through the localizer and continues southwesterly with no air traffic control intervention. The aircraft on the approach to Runway 17L continues its approach.

**Scenario 2:** An aircraft being vectored to the localizer to Runway 13R flies through the localizer and continues southwesterly with no air traffic control intervention. The aircraft on the Runway 17L approach performs a missed approach.

**Scenario 3:** An aircraft established on the localizer to Runway 17L turns to a heading of 080° and flies at a level altitude, without air traffic control intervention, toward an aircraft being vectored to the localizer to Runway 13R.

Scenarios 4, 5, and 6 are identical to Scenarios 1, 2, and 3, respectively, except that air traffic control does intervene to correct the situation. The scenarios were designed to simulate the types of blunders, which could lead to a loss of separation. The scenarios are summarized in table 4.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>RWY 17L, DFW</th>
<th>RWY 13R, LOVE FIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/A</td>
<td>Evading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level</td>
</tr>
<tr>
<td>1</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>2</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>N/A</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>N/A</td>
<td>YES</td>
</tr>
</tbody>
</table>

7.3 Basic Risk Computation.

7.3.1 Definition of a TCV. Although the definition of a collision of two aircraft is obvious, a definition, which can be used in mathematical analysis, is not as obvious and may be considered by some to be subjective. Since aircraft are basically long tubular structures with various protuberances, it is possible that two aircraft could pass very close to one another without touching. On the other hand, the aircraft could simply touch wing tips with the centers of gravity far removed. For this reason it was decided to place the evading aircraft in the center of a hypothetical sphere and determine whether or not the center of gravity of an approaching aircraft penetrates that sphere. It will be assumed that such a penetration would result in a collision. Obviously, not all such penetrations would result in collisions, but in mathematical analysis some simplifying assumptions must be made. The choice of the radius of this sphere is somewhat subjective. It must be at least as large as the wingspan of the largest aircraft, which will be involved in parallel approach operations, and it must be at least as large as...
the wingspan of aircraft in the foreseeable future. For these reasons the radius of the sphere was chosen to be 500 feet. Since an incursion of the approaching aircraft into the 500-foot sphere of the evading aircraft does not guarantee a collision, it will be called a Test Criterion Violation (TCV).

7.3.2 Basic Risk Equation. A TCV can occur if an aircraft departs the approach at either DFW or DAL. The reason for the departure could be a failure to intercept the localizer to runway 13L/R at DAL, a missed approach from runway 17L at DFW, or an eastward turn from runway 17L at DFW toward the inbound traffic to runway 13L/R at DAL. The turn from runway 17L toward runways 13L/R could be the result of a blunder on runway 17C at DFW which forced air traffic control to break out the aircraft on 17L toward 13L/R, or it could be the result of a blunder or early missed approach by the aircraft on 17L. For simplicity each of these events will be referred to as a blunder.

Although a TCV does not necessarily result in a collision, for simplicity and in order to equate the probability of a TCV to the existing accident rate, it will be assumed that a TCV will result in a collision and that a collision will result in the loss of both aircraft. Therefore, in order to simplify the analysis, a TCV will be assumed to result in two fatal accidents. Since in normal operations the probability of a TCV is insignificant, a TCV can only occur if a blunder occurs.

Using the notation \( P(\text{event}) \) to indicate the probability that an event will occur and \( P(\text{event} \mid \text{event 2}) \) to indicate the probability that event 1 will occur given that event 2 has already occurred, the discussion above indicates that the probability of a collision may be written as:

\[
P(\text{collision}) = P(\text{TCV})
\]

\[(1) \quad = P(\text{TCV and blunder})\]

\[= P(\text{TCV} \mid \text{blunder}) \times P(\text{blunder}).\]

In order to compute the probability of a collision or TCV it is necessary to compute or estimate two factors. The first factor, \( P(\text{TCV} \mid \text{blunder}) \) may be estimated from data collected during the simulation of this study. The simulation is designed to determine the probability that a TCV will occur when a blunder occurs. The second factor, \( P(\text{blunder}) \) is more difficult to estimate since it is extremely small and reliable historical data is not available. However, approximate bounds may be placed on the size of \( P(\text{blunder}) \) by experienced ATC personnel. Since \( P(\text{TCV}) \) depends on a factor whose estimation is in doubt, it is desirable to eliminate the doubtful factor.

From historical data the probability of a fatal accident during an approach under instrument meteorological conditions may be determined and used to find an acceptable risk of a TCV. In this way, the only missing variable in the equation would be \( P(\text{blunder}) \). The formula could then be used to solve for \( P(\text{blunder}) \). Thus \( P(\text{blunder}) \) is given by:

\[
P(\text{blunder}) = P(\text{TCV}) / (P(\text{TCV} \mid \text{blunder})).\]

(2)
The value, P(blunder) would not represent the actual probability of a blunder since that value is unknown, instead, it would represent a blunder probability which the system could tolerate and which would provide an acceptable level of risk represented by P(TCV). A large value of P(blunder) would be desirable since it would indicate the system could tolerate a large blunder probability and still meet the acceptable risk level, P(TCV). A very small value of P(blunder) would be undesirable since it is known that the actual blunder rate is small, but the order of magnitude is in question.

7.4 Determination of Acceptable Risk.

7.4.1 Phases of Flight. In order to find an acceptable probability of an accident due to a collision of aircraft on adjacent approaches, a general systems approach to the overall flight operation is discussed first. The flight operation is defined to be the entire sequence of events in a flight from starting the engine(s) in preparation for departure to shutting down the engine(s) at the destination. The sequence of events can be defined with varying degrees of detail; however, for the purposes of this discussion, the following sequence of events seems appropriate:

a. Start and taxi
b. Take-off
c. Climb to cruise altitude
d. Cruise en route
e. Descent and initial approach
f. Final approach
g. Landing, roll-out, taxi, shutdown.

This sequence was chosen because historical accident data is reported using this sequence.

7.4.2 Estimating Phase Risks. Using data made available by the National Transportation Safety Board (NTSB) and the FAA, the fatal accident rates by departure for air-carrier operations for the years 1983-88 have been made and are shown in table 5. The accident count from which these rates were determined includes all reported air-carrier accidents. The accidents reported by NTSB may or may not be due to system failures or pilot errors. For example, a fatal accident involving a ground crew member during the push back from the jetway is reported. For this reason, only accidents caused by system failures or pilot errors are used in the determination of the phase rates. From data supplied by the FAA, the number of air-carrier operations or departures is estimated to be about 33.3 million. The phase rate is determined by dividing the number of fatal accidents by the number of departures.

7.4.3 Estimating Final Approach Risk. Since the NTSB reported two fatal accidents during the approach phase, the estimated rate for the final approach segment is $6 \times 10^{-8}$ fatal accidents per departure. Since most approaches are flown in visual flight conditions using visual flight rules (VFR), it is necessary to adjust the rate to reflect the number of approaches under instrument meteorological conditions using IFR. The number of instrument approaches is no longer recorded by the FAA. However, using data available in the FAA Statistical Handbook
of Aviation, 1970, the percentage of precision approaches is estimated to be about 15 percent, the percentage of non-precision approaches is estimated to be about 2 percent, and the number of visual approaches is estimated to be about 85 percent. Since average weather conditions are assumed to be constant through the years, these percentages are assumed to still be accurate.

Table 5. FATAL ACCIDENT STATISTICS.

<table>
<thead>
<tr>
<th>Phase of Flight</th>
<th>Reported Fatal Accidents</th>
<th>Fatal Accident Rate (per Approach)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start and Taxi</td>
<td>1</td>
<td>$2.9998 \times 10^{-8}$</td>
</tr>
<tr>
<td>Take-off</td>
<td>6</td>
<td>$1.7999 \times 10^{-7}$</td>
</tr>
<tr>
<td>Climb</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Cruise</td>
<td>3</td>
<td>$8.9995 \times 10^{-8}$</td>
</tr>
<tr>
<td>Descent</td>
<td>1</td>
<td>$2.9998 \times 10^{-8}$</td>
</tr>
<tr>
<td>Approach</td>
<td>2</td>
<td>$5.9997 \times 10^{-8}$</td>
</tr>
<tr>
<td>Landing</td>
<td>1</td>
<td>$2.9998 \times 10^{-8}$</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>$4.1998 \times 10^{-7}$</td>
</tr>
</tbody>
</table>

Since about 33.3 million operations were recorded for the years 1983-88, the number of precision approaches is about 15 percent of 33.3 million or 5 million precision approaches. The two fatal accidents reported in the time period both occurred during precision approaches. This leads to an estimated fatal accident rate for precision approaches during the same period of time of $4 \times 10^{-7}$ or about 1 fatal accident per 2.5 million approaches.

7.4.4 Target Level of Safety. The final approach, whether precision, non-precision, or VFR is not just a single operation, but is composed of several operations requiring certain systems for their successful completion. In order to determine the risk of collision with an aircraft on the adjacent glide path, it is necessary to determine each operation, which must be performed and each system, which must function to successfully complete the approach without an accident. The following is a list of events which could produce an accident during an instrument approach:

1. Collision with an obstacle during the instrument portion of the approach.
2. Collision with an obstacle during the visual portion of the approach.
3. Pilot failure due to mental or physiological malfunction.
4. Failure of aircraft systems except engine, structures, electronic.
5. Aircraft structural failure.
7. Failure of approach guidance electronics, ground and air.
8. Natural environmental phenomenon.
10. Midair collision with an aircraft on an adjacent approach.
Event 9 represents a collision with another aircraft which is not established on an adjacent, parallel approach, while event 10 represents a collision with an aircraft which is, or has been (in case of a blunder), established on a parallel approach. Using these events as the ones which could produce an accident if they occur, then the probability of an accident on the ILS approach, \( P(A) \), would be:

\[
P(A) = 1 - P(A').
\]

The probability that an accident will not occur, \( P(A') \) is the probability that event 1 does not occur, \( P(1') \), and event 2 does not occur, \( P(2') \), ..., and event 10 does not occur, \( P(10') \). Assuming that the events are independent, the probability that an accident does not occur is:

\[
P(A') = P(1')P(2')P(3') \ldots P(10').
\]

The probability of an accident is then given by:

\[
P(A) = 1 - P(1')P(2')P(3') \ldots P(10').
\]

\[
P(A) = 1 - (1 - P(1))(1 - P(2)) \ldots (1 - P(10)) = P(1) + P(2) + \ldots + P(10) + Q,
\]

where \( Q \) represents a sum of terms each involving products of probabilities, \( P(1) \) through \( P(10) \). Since each individual probability is very small, at most \( 4 \times 10^{-3} \), each term of \( Q \) must be of the order \( 10^{-15} \) or less. Neglecting these terms, the probability of an accident, \( P(A) \), is given by:

\[
P(A) = P(1) + P(2) + \ldots + P(10).
\]

Although enormous amounts of time and money are spent on accident investigations, it is extremely difficult to pinpoint the exact cause of an accident. It is extremely difficult in many cases to determine which of the nine causes referred to above should be assigned to a particular accident. Because of the rarity of accidents due to each of the causes, much more data than currently available would be necessary to estimate the risk of each of the nine causes. It is apparent estimates of the nine risks are, for practical purposes, impossible and a different approach to the problem is necessary.

This same problem is encountered in the design of an aircraft. According to FAR 25.1309, it was assumed there are 100 potential failure conditions in an airplane which could contribute significantly to the cause of a serious accident. Since test data, historical data, or even theoretical estimates are unavailable for most of the causes, the allowable overall risk of a serious accident was apportioned equally among these conditions, resulting in an allowable risk for each of the failure conditions equal to \( 1/100 \) of the total risk.

Since ten causes of a fatal accident during simultaneous approaches to DFW on 17L and DAL on 13L/R can be defined, it is reasonable to assign an equal probability to each of the causes. The
overall probability of a fatal accident during a parallel approach is the sum of the probabilities of the component causes, each cause should be allocated 1/10 of the total probability. This leads to an allowable probability of $4 \times 10^{-8}$, or 1 fatal accident per 25 million approaches. The allowable probability of a fatal accident is called the Target Level of Safety. This approach should lead to a conservative risk allowance for collision since the risk of some of the ten causes may be so small as to be insignificant. This means there are possibly fewer than ten significant causes so the total risk could have been divided by a smaller number resulting in a larger allowable risk for collision.

7.4.5 Confidence Intervals. In the ASAT simulation of possible blunders at DFW and DAL, aircraft are placed at random in starting gates with random airspeeds and altitudes within established bounds. The aircraft are then flown through a blunder scenario, with or without ATC intervention, and the result is either a TCV or a non-TCV. In a Bernoulli process, there are only two outcomes to an experiment, usually called success and failure. The probability of either success or failure is simply the ratio of the event to the total number of observations during the experiment. The probability of a TCV during a blunder may be estimated as the ratio of the number of TCV's to the total number of blunders. When an experiment is performed from a known Bernoulli process, such as flipping a coin or rolling a die, it is known the observed estimate of the probability will differ from the theoretic or underlying probability and that different experiments will produce different estimates of the same underlying probability. Thus the ratio of TCV's to blunders should not be used directly as the estimate of the underlying probability.

From the theory of Bernoulli processes, confidence intervals of the underlying probability may be determined from the observed data. A confidence interval gives a measure of the variation from the underlying probability that may be observed in experimental data. Confidence intervals always have a probability or confidence level associated with them. A confidence interval might be termed a 0.99 interval. This would mean that if 100 different experiments were performed to estimate the underlying probability, then it would be expected that about 99 of the confidence intervals computed from the observed data would contain the underlying probability.

Formulae exist for the computation of confidence intervals of Bernoulli probabilities. Since the probability of a TCV is very small, the appropriate formulae for the upper and lower limits of a 0.99 confidence interval are as follows:

$$
\sum_{y=0}^{k} c(n, y)p^y(1-p)^{n-y} = 0.005
$$

$$
\sum_{y=k}^{n} c(n, y)p^y(1-p)^{n-y} = 0.005
$$

The value of the probability, $p$, must be found using numerical methods such as Newton's method or the bisection method.
Since in a computation of risk conservatism is extremely important, the value associated with the upper limit of the confidence interval is the only one of interest. The upper limit of a 0.99 confidence interval represents a value which is almost certainly larger than the actual underlying probability. Thus use of the upper confidence interval bound will provide a conservative estimate of the actual probability.

7.4.6 Estimating Collision Risk. Six blunder scenarios were designed to simulate blunders at DFW or DAL. In scenario one, an aircraft being vectored to the localizer to runway 13L/R at DAL flies through the localizer and continues southwesterly with no ATC intervention. The aircraft on the DFW approach to runway 17L continues its approach. In scenario two, an aircraft being vectored to the localizer to runway 13L/R at DAL flies through the localizer and continues southwesterly with no ATC intervention. The aircraft on the DFW approach performs a missed approach. In scenario three, an aircraft established on the localizer to runway 17L at DFW turns to a heading of 080° and flies at a level altitude, without controller intervention, toward an aircraft being vectored toward the localizer to runway 13L/R at DAL. Scenarios four, five, and six are identical to scenarios one, two, and three, respectively, except ATC does intervene to correct the situation.

7.4.6.1 Scenario One Risk. Scenario one was simulated 200,000 times. The observed number of TCV's was 4, resulting in an observed TCV rate of 1 per 50,000. The upper confidence limit was determined from equation 8 to be 0.0000630. Conversion of the confidence limit into a TCV rate results in a possible TCV rate of 1 TCV per 15,873 blunders. The maximum blunder rate that can be tolerated and still meet the target level of safety is determined from equation 2. With the upper confidence limit as the TCV rate and a correction factor of 2 accidents per TCV, equation 2 becomes:

\[
\frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{15873 \text{ blunder}}{1 \text{ TCV}} = \frac{1 \text{ blunder}}{1575 \text{ app pair}}
\]

Equation 10 indicates a blunder of the type simulated in scenario one could occur at the rate of 1 blunder per 1,575 approach pairs and still maintain the target level of safety. According to data supplied by APO-110, the annual number of arrivals at DAL is approximately 110,000. If about 70 percent land on runways DAL 13R/L, and if IMC conditions prevail about 15 percent of the time, then about 960 instrument approaches are performed on runways DAL 13R/L per month. Anecdotal evidence indicates that about 1 blunder per month of the type simulated in scenarios one and four. This results in a blunder rate of about 1/960 approach pairs. Since the maximum allowable blunder rate found for scenario one is smaller than 1/960, the risk associated with the type of blunder simulated in scenario one, without ATC intervention, is unacceptable.

7.4.6.2 Scenario Two Risk. Scenario two was simulated 200,000 times. The observed number of TCV's was 3 resulting in an observed TCV rate of 1 per 66,667. The upper confidence limit was determined from equation 8 to be 0.0000549. Conversion of the confidence limit into a TCV rate results in a possible TCV rate of 1 TCV per 18,215 blunders. The maximum blunder rate that can be tolerated and still meet the target level of safety is determined from equation 2 with a modification because of the missed approach. Since scenario
two can only occur if a missed approach from runway DFW 17L occurs simultaneously with a blunder from DAL 13R, equation 2 is changed as follows:

\[
P(\text{collision}) = P(\text{TCV})
\]

\[
= P(\text{TCV and blunder and missed approach})
\]

\[
= P(\text{TCV | blunder and missed approach}) \times P(\text{missed approach | blunder}) \times P(\text{blunder}).
\]

The simulation of scenario 2 provides an estimate of \( P(\text{TCV | blunder and missed approach}) \). Therefore, \( P(\text{TCV | blunder and missed approach}) \) is estimated to be \( \frac{1}{18215} \). The second factor, \( P(\text{missed approach | blunder}) \) is the probability of a missed approach on runway 17L given that a blunder occurs on the approach to runway 13L/R. It is generally accepted that the rate of missed approaches is no more than \( \frac{1}{100} \). If it is assumed that during every blunder on runway 13L/R there is a corresponding aircraft performing an approach on runway 17L, only about 1 missed approach per 100 blunders will occur. Therefore, \( P(\text{missed approach | blunder}) \) is estimated to be \( \frac{1}{100} \). The maximum blunder rate that can be tolerated is given by:

\[
\frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{18215 \text{ miss}}{1 \text{ TCV}} \times \frac{100 \text{ blunder}}{1 \text{ miss}} = \frac{1 \text{ blunder}}{14 \text{ app pair}}
\]

This result indicates if a TCV of the type simulated in scenario two is the only risk of collision, then the blunder rate on runways 13L/R could be as large as 1/14 and the target level of safety would be met. The reason the maximum rate is so large is because during only one in one hundred blunders will there be a missed approach occurring on runway 17L. Since the maximum allowable blunder rate found for scenario two is larger than \( \frac{1}{960} \), the risk associated with the type of blunder simulated in scenario two, without ATC intervention, is acceptable.

7.4.6.3 Scenario Three Risk. Scenario three was simulated 200,000 times. The observed number of TCV's was 538 resulting in an observed TCV rate of \( \frac{1}{372} \). The upper confidence limit was determined from equation 8 to be 0.0030029. Conversion of the confidence limit into a TCV rate results in a possible TCV rate of 1 TCV per 333 blunders. Since scenario 3 does not require the occurrence of two simultaneous events as does scenario 2, the maximum acceptable blunder rate may be computed from equation 2. The maximum acceptable blunder rate is given by:

\[
\frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{372 \text{ blunder}}{1 \text{ TCV}} = \frac{1 \text{ blunder}}{67,204 \text{ app pair}}
\]

The type of blunder simulated in scenario three is, intuitively, a far more rare event than the blunders simulated in scenarios one and two. According to the Administrator's Fact Book, June 1996, the number of tower operations at DFW in 1995 was 880,000. If half of these operations were approaches, approximately 440,000 approaches were flown to DFW in 1995. If 15 percent
of the approaches are in IMC conditions, then about 66,000 instrument approaches were performed at DFW in 1995. Anecdotal evidence provided by tower personnel at the DFW tower indicates that from 1 to 3 breakouts occur annually. This would result in a blunder rate of 1/66000 to 1/22000. Therefore, since it is likely that the actual rate of blunders, as simulated in scenario three, is larger than 1/67,204, the type of blunder simulated in scenario three, without ATC intervention, would not meet the target level of safety and would be unacceptable.

7.4.6.4 Scenario Four Risk. Scenario four was simulated 200,000 times. Scenario four is the same as scenario one with ATC intervention. The observed number of TCV's was 0, resulting in an observed TCV rate of 0. However, the upper confidence limit was determined from equation 8 to be 0.0000265. Conversion of the confidence limit into a TCV rate results in a possible TCV rate of 1 TCV per 37736 blunders. The maximum allowable blunder rate is given by equation 14. Equation 14 indicates that one blunder of the type simulated in scenario one could occur at the rate of 1 blunder per 663 approach pairs and still maintain the target level of safety.

$$\frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{37736 \text{ blunder}}{1 \text{ TCV}} = \frac{1 \text{ blunder}}{663 \text{ app pair}}$$

Since the maximum allowable blunder rate found for scenario four is larger than the estimated actual blunder rate of 1/960, the risk resulting from the type of blunder simulated in scenario four, with ATC intervention, is less than the target level of safety and is acceptable.

7.4.6.5 Scenario Five Risk. Scenario five was simulated 200,000 times. Scenario five is the same as scenario two with air traffic control intervention. The observed number of TCV's was 0, resulting in an observed TCV rate of 0. The upper confidence limit was determined from equation 8 to be 0.0000265. Conversion of the confidence limit to a TCV rate results in a possible TCV rate of 1 TCV per 37736 blunders. The maximum allowable blunder rate would be given by equation 15. Equation 15 contains a correction factor for the missed approach from Runway 17L.

$$\frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{37736 \text{ miss}}{1 \text{ TCV}} \times \frac{100 \text{ blunder}}{1 \text{ miss}} = \frac{1 \text{ blunder}}{7 \text{ app pair}}$$

Equation 15 indicates one blunder of the type simulated in scenario five could occur at the rate of 1 blunder per 7 approach pairs and still maintain the target level of safety. Since the maximum allowable blunder rate found for scenario five is larger than the estimated actual blunder rate of 1/960, the risk resulting from the type of blunder simulated in scenario five, with air traffic control intervention, is less than the target level of safety and is acceptable.

7.4.6.6 Scenario Six Risk. Scenario six was simulated 200,000 times. Scenario six is the same as scenario three with ATC intervention. The observed number of TCV's was 6, resulting in an observed TCV rate of 1 per 33,333. The upper confidence limit was determined from equation 8 to be 0.0000783. Conversion of the confidence limit into a TCV...
rate results in a possible TCV rate of 1 TCV per 12,771 blunders. The maximum blunder rate that can be tolerated and still meet the target level of safety is determined from equation 15.

\[
(16) \quad \frac{1 \text{ acc}}{25 \text{ mill apps}} \times \frac{2 \text{ apps}}{1 \text{ app pair}} \times \frac{1 \text{ TCV}}{2 \text{ acc}} \times \frac{12771 \text{ blunder}}{1 \text{ TCV}} = \frac{1 \text{ blunder}}{1958 \text{ app pair}}
\]

Equation 15 indicates one blunder of the type simulated in scenario six could occur at the rate of 1 blunder per 1,958 approach pairs and still maintain the target level of safety. Since the maximum allowable blunder rate found for scenario six is larger than the estimated actual blunder rate of 1/22,000, the risk resulting from the type of blunder simulated in scenario six, with ATC intervention, is less than the target level of safety and is acceptable.

### 7.4.7 Summary of Risk Analysis

The risk associated with a blunder may be quantified by simulation of three blunder scenarios. In order to determine the acceptability of the risk associated with a blunder scenario, the scenario risk is compared to the target level of safety to determine a maximum acceptable blunder rate. The maximum acceptable blunder rate is the maximum rate that blunders of the type simulated in the scenario can occur while maintaining the risk of collision at or below the target level of safety.

Scenarios one and four simulate a blunder in which an aircraft flies through the localizer to runway DAL 13R. An aircraft on the ILS approach to runway DFW 17L continues the approach. In scenario one without ATC intervention, four TCV's were observed. However, in scenario four with ATC intervention, no TCV's were observed. The maximum allowable blunder rate was found to be 1/1575 for scenario one, and it was found to be 1/663 for scenario four. Since the maximum allowable blunder rate found for scenario four is larger than the estimated actual blunder rate of 1/960, the risk resulting from the type of blunder simulated in scenario four, with ATC intervention, is less than the target level of safety and is acceptable. However, the risk associated with scenario one, without ATC intervention, was found to be unacceptable.

Scenarios two and five simulate a blunder in which an aircraft flies through the localizer to runway DAL 13R. An aircraft on the ILS approach to runway DFW 17L executes a missed approach. The simulation and risk analysis indicates the maximum acceptable blunder rate for scenarios two and five are both very large. A primary reason for the size of the maximum acceptable blunder rate is the infrequency of missed approaches. Because the maximum acceptable blunder rate is much larger than the expected blunder rate, the risk associated with blunders of the type simulated in scenarios two and five is less than the target level of safety and is acceptable.

Scenarios three and six simulate a 90° breakout from runway DFW 17L toward the traffic entering the localizer to runway DAL 13R. In scenario three, ATC intervention was not used and the result was a small (1/67,204) maximum acceptable blunder rate. Since the actual blunder rate is considered to be larger, the risk of the blunder simulated in scenario three would be unacceptable. In scenario six, ATC intervention resulted in a significantly smaller number of TCV's. The result was a much larger (1/1958) maximum acceptable blunder rate. These rates are well below the maximum acceptable blunder rate of 1/1958. Therefore, the risk resulting from
the type of blunder simulated in scenario six with ATC intervention is less than the target level of safety and is acceptable.

Three types of blunders were simulated with and without ATC intervention. The analysis indicated the risk resulting from all three types of blunders, with ATC intervention, meets the target level of safety and is acceptable.

8.0 CONCLUSION.

A review of all sections of this document indicates the procedures outlined in alternative 8, as described in paragraph 3.0, is the preferred alternative. Furthermore, the procedures described under alternative 8 have been validated in two separate simulations, the “Real Time” simulations conducted by DFW TRACON and by the computer based “Risk Analysis” conducted by AFS-420F-FAA. The risk analysis developed by AFS-420 demonstrated alternative 8 would meet the target level of safety when using a dedicated radar monitor position with the distribution of controller response times measured in the real time simulation. The risk analysis also demonstrated that without the dedicated radar monitor position, the target level of safety could not be met.

Upon completion of the risk analysis, representatives of AFS-420 conducted a thorough briefing to the members of the study group. It was pointed out that a dedicated radar position with controllers able to maintain the distribution of response measured in the real time simulation is necessary in order to meet the target level of safety. All members of the group accepted the procedures outlined in alternative 8. Subsequent action by DFW TRACON instituted these procedures upon the commissioning of Runway 17L at DFW on October 1, 1996. Figure 11 depicts the procedures implemented.